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[Self-directed therapy programmes for arm rehabilitation after stroke: a systematic review.](#)

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Title: “Self-directed therapy programmes for arm rehabilitation after stroke: a systematic review.”

Running title: “Self-directed arm interventions”

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Abstract

Aim: To investigate the effectiveness of self-directed arm interventions in adult stroke survivors.

Methods: A systematic review of Medline, EMBASE; CINAHL; SCOPUS and IEEEExplore up to February 2018 was carried out. Studies of stroke arm interventions were included where more than 50% of the time spent in therapy was initiated and carried out by the participant. Quality of the evidence was assessed using the Cochrane risk of bias tool.

Results: 40 studies (n= 1172 participants) were included (19 RCTs and 21 before-after studies). Studies were grouped according to no-technology or the main additional technology used (no technology n=5; interactive gaming n=6; electrical stimulation n=11; constraint-induced movement therapy n=6; robotic and dynamic orthotic devices n= 8; mirror therapy n= 1; tele-rehabilitation n=2; wearable devices n=1).

A beneficial effect on arm function was found for self-directed interventions using constraint-induced movement therapy (n=105; SMD 0.39, 95% confidence interval -0.00 to 0.78) and electrical stimulation (n=94; SMD 0.50, 95% confidence interval 0.08 to 0.91). Constraint-induced movement therapy and therapy programmes without technology improved independence in activities of daily living. Sensitivity analysis demonstrated arm function benefit for patients >12 months post-stroke (n=145; SMD 0.52, 95% CI 0.21, 0.82) but not at 0-3; 3-6 or 6-12 months.

Conclusions: Self-directed interventions can enhance arm recovery after stroke but the effect varies according to the approach used and timing. There were benefits identified from self-directed delivery of constraint-induced movement therapy, electrical stimulation and therapy programmes that increase practice without using additional technology.

Introduction

There is evidence that optimising recovery of arm function after stroke requires a high level of intensive rehabilitation¹⁻³ which can be challenging for healthcare providers^{4, 5}. One way to increase therapeutic activity without placing an extra demand on resources is via programmes where patients independently perform recovery activities away from a clinical setting. The structure and format of these programmes can vary with some following a set of structured exercises or functional activities whilst others simply promote and facilitate opportunities to enhance use of the stroke arm in normal routines beyond ‘usual care’. In addition, an increasing variety of technologies is being developed and evaluated to promote recovery activities without increasing demands on therapists’ time⁶.

The term ‘self-directed interventions’ can be used to encompass all of these modalities for activity promotion. Whilst the value of specific arm interventions has already been described³, the evidence relating to the delivery of self-directed arm rehabilitation across therapeutic modalities has not previously been summarised and could provide important insights about using this approach to enhance delivery. Due to the implications for patient selection, user acceptability, staff training and resources, it is also of particular interest whether differences exist in the feasibility and effect of arm rehabilitation according to the type of technology being delivered under self-direction.

The aim of this review was to firstly identify and describe the content of interventions for rehabilitation of the arm after stroke which have taken a predominantly self-directed approach (with or without the involvement of technology) and secondly to report their

effectiveness for improving arm function and/or increasing use of the stroke arm in daily activities when sufficient trial data were available.

Methods

The review was conducted according to guidelines set out by the Cochrane collaboration⁷ . The protocol was published on the PROSPERO International prospective register of systematic reviews website (Reference number: 38619)⁸.

Electronic searches of MEDLINE; EMBASE; CINAHL; SCOPUS and IEEEXplore were carried out from the time of origin to February 2018. The search strategy used a combination of selected MeSH terms with keywords for MEDLINE, which was then altered appropriately for other databases⁸ (Appendix 1). A search of the Cochrane database of systematic reviews was also conducted and the reference lists of relevant reviews screened manually for additional studies.

We included studies of self-directed arm interventions for participants over the age of 18 with any stroke-related arm deficit regardless of time since onset. Populations with mixed impairment aetiology were included if at least 50% of participants had experienced a stroke. An intervention was classified as self-directed if more than 50% of the overall intended duration of therapy practice, was independently initiated and carried out by the participant outside of direct contact sessions in accordance with a pre-defined study protocol.

When identified studies described that direct clinical or research supervision was required for some aspect of the intervention (e.g. application of electrical stimulation electrodes, or review of functional activity goals) the methods and results were carefully scrutinised to be sure that overall there was a dominant self-directed component. If the self-directed therapy formed part of another programme (e.g. the transfer package of constraint induced movement therapy), then the self-directed component of the programme needed to be clearly described or evidence provided that participants had recorded details of their independent practice.

In order to describe the full range of self-directed interventions, any study design was accepted providing that it reported an arm function outcome for two or more participants.

The primary review author (RDS) initially screened the titles of all records and removed duplicates. The titles and abstracts of the remaining papers were independently assessed by two review authors (RDS and CP) to identify studies meeting inclusion criteria. The full text of all potentially relevant papers were retrieved and final studies selected. Discrepancies were resolved through discussion and involvement of a third author (SM).

A data extraction form was designed to meet the criteria of the review and tested on the first five studies. Data were extracted by the primary author (RDS) including: study design; sample size; intervention content; amount of therapy practice; amount of therapist time; main outcomes and adherence to protocol. Any equivocal data were discussed and resolved between all authors. Interventions were grouped according to no-technology or the type of technology described. Where an intervention involved more than one form of technology a joint author decision was made regarding the primary technology being tested. Devices were

still included if they had not been specifically designed with a rehabilitation purpose provided they followed a protocol intended to help people to recover arm movement. Where data were missing or incomplete, authors were contacted.

To report effectiveness, meta-analysis was carried out with data from those studies where participants had been randomised and clinical outcomes of arm function and / or independent use in daily activities were reported. For studies with a cross-over design, only the first phase data (prior to cross-over) were included in the meta-analysis to avoid any possibility of data contamination through carryover or learning effects.

Treatment effect sizes were calculated using Revman 5 software⁹ based on mean scores and standard deviations from the randomised studies. Where the standard error or confidence interval was reported the standard deviation was calculated using formulas provided in the Cochrane handbook's guidelines⁷. As studies were small in size, mean change from baseline was used where available to allow for a more accurate comparison between control and intervention⁷.

Due to the wide range of interventions being studied we anticipated that a variety of outcome measures would be reported. For this reason meta-analysis was carried out within each technology sub-group in an attempt to reduce heterogeneity. When the same outcome measure was used by all studies within a sub-group the mean difference was calculated, otherwise outcomes were pooled using the standardised mean difference. Most outcome measures rated improvement by an increase in score however, where a reduced outcome

score indicated improvement (i.e. a decrease in time taken to complete a task) the scale direction was aligned with others by multiplying the mean score by -1⁷.

Each of the randomised studies underwent an assessment of risk of bias using the Cochrane Risk of bias tool⁷.

There were two pre-planned sensitivity analyses. One was to look at the influence of time post stroke and the second was to consider if there was a benefit shown for more time spent practicing. The amount of time post stroke was categorised as < 3months; 3-6 months; 6 to 12 months and > 12 months based on the mean time post-stroke reported by original authors. The amount of time spent in self-directed versus supervised therapy practice was calculated according to each study's protocol (see Table 1). If the precise amount was unclear, a minimum estimated amount of time was calculated as follows: where a range was given (e.g. 1-3 hours per day) the lower value was used; where amount of time was described as a number of sessions each session was estimated at 30 minutes unless otherwise stated; a telephone contact was allocated 15 minutes per contact. Any pre-intervention training was excluded from the amount of practice i.e. only the amount provided within the actual therapy programme was included.

Results

The PRISMA diagram¹⁰ in Figure 1 summarises the results of the literature search. The searches identified 1380 records of which 128 were removed as duplicates. One thousand two hundred and fifty-two records were screened by primary author (RDS) and the full texts of 106 articles subsequently retrieved for full text assessment. Sixty-six of these records were excluded leaving a total of 40 studies (1172 participants) for inclusion. Table one provides an

overview of the studies interventions including 19 randomised controlled / cross-over trials¹¹⁻²⁹ and 21 before and after studies³⁰⁻⁵⁰

The amount of time spent in therapy practice across all interventions ranged from seven³⁶ hours to 366⁴⁰ hours over a period that ranged from two weeks^{21, 36-38, 42} to five months. It was not possible to calculate the amount of practice time for one study⁴⁹ as the amount of activity was described as a summary value of accelerometer data (i.e. signal vector magnitude) rather than time.

Most interventions included additional technology with only five studies that did not (^{12, 17, 35, 38, 45}). All interventions in the “no technology” group (Table 1) involved some form of repetitive functional task practice ranging from simple reaching and grasp of everyday objects to more complex functional tasks. Typically these approaches relied on low-cost equipment most of which could be easily sourced at home. Only two studies included participants who were still inpatients although both these interventions would also be suitable for home-based use. Two studies used participant-identified goals to assist in the choice of tasks to practise^{12, 26}. Adherence to programmes was high with the total amount of therapy practice ranging from 26 to 56 hours of which 67% to 93% was self-directed across a time period ranging between 2 and 10 weeks.

Studies that used technology fell into seven groups according to the type used (Table 1). There was some overlap within these groups as several studies employed more than one mode of technology in order to deliver their intervention e.g. computer games often

supported use of the stroke arm during sessions with robotic devices^{27, 29, 40, 42, 43, 46-48}. Tele-rehabilitation was used alongside interventions such as constraint-induced movement therapy^{29, 34, 40, 42} as a method of delivering or monitoring the intervention without the need for face to face therapist contact^{27, 36}. The wearable device monitored the amount of use of the stroke hand and provided feedback to the wearer to encourage them to use it more within a functional task practice programme⁴⁹ without additional technology.

The most frequently studied intervention was electrical stimulation which also recorded the highest consistent amounts of practice ranging from 20 hours across a 4 week programme⁴⁴ to 106 hours over 5 months¹⁶. Participants in the electrical stimulation group were all more than six months post-stroke at the time of enrolment and demonstrated regular self-directed use of the intervention over long periods of time. Participants adhered well to the electrical stimulation treatment plans consisting of both surface electrodes^{14-16, 18, 24, 30, 31, 41, 44} and implanted percutaneous electrodes^{32, 45} and triggered by timed and cyclic stimulation^{11, 14, 24, 30}; EMG^{15, 16, 18, 41}; or closed-loop systems^{24, 32, 45}.

Interventions using constraint-induced movement therapy also demonstrated that participants were able to adhere to a large amount of unsupervised therapy practice ranging from 10 hours across two weeks²¹ to 350 hours over a 10 week period⁴⁰. Participants in this group were all more than two months post stroke.

Adherence to the programme was generally poor in the interactive gaming interventions. High attrition was recorded in the intervention versus the control group for one study²², whilst another study indicated that fewer sessions of longer duration may be preferable to daily sessions³³. When interactive gaming was used to support robotic and orthotic device interventions, participants also reported less than the prescribed amount of therapy practice^{20, 39, 43}, which was not noted for studies in the same intervention category that included conventional task practice^{23, 27, 28}. Participants reported that the games “lacked complexity”⁴³ and that “more attention towards motivational strategies is needed”²⁹. Interactive gaming using the Nintendo Wii™ was an exception^{11, 37}. Two studies found that the intervention was well tolerated and beneficial for arm recovery, although one reported equivalent improvement through practice of selected activities from the Graded Repetitive Arm Supplementary Programme¹⁷, which was more cost effective¹¹.

Results of Meta-analysis

Effects of Self-directed interventions on arm function / impairment

A total of 16 randomised studies were included in the analyses^{11-14, 17-28}. Two studies were excluded due to insufficient methodological rigour or poor reporting quality^{15, 16} and a third did not report on clinical outcomes²⁹. None of the studies made a direct comparison between an intervention that was self-directed with the same intervention delivered under supervision of a therapist and all except three studies used a dose-matched control intervention.

Due to heterogeneity between the types of interventions and the range of outcome assessments employed, an overall treatment effect for self-directed interventions on arm function was not considered meaningful. Instead, as described below, data were analysed within each sub-group (Figure 3). Note that the study in the wearable devices group did not meet the criteria for inclusion in the meta-analysis.

Three studies^{12, 17, 26} in the No Technology group were included in the analysis, all of which measured arm function using the Action Research Arm Test (ARAT). For the two pilot randomised controlled trials^{12, 26} the change in scores before and after the intervention were used in the analysis whilst the end scores were used for the randomised controlled trial¹⁷. Analysis narrowly failed to show a statistically significant benefit of the intervention on arm function (n=169; mean difference (MD) 1.96, 95% confidence interval (CI) -0.99 to 4.92).

Within the interactive gaming group, two studies were considered suitable for analysis^{11, 22}. The impact of self-directed interactive gaming programmes did not indicate a benefit for arm function (n=231; SMD 0.11, 95% CI -0.37 to 0.15).

Data were available for three studies^{14, 18, 24} using electrical stimulation. All used surface electrodes and compared the intervention with a sham device. A mixture of outcome measures were used (Fugl-Meyer: end score²⁴, Jebsen Taylor test: change score¹⁴ and Box and blocks: end score¹⁸) necessitating the use of a standardised mean difference. There was a

statistically significant effect on arm function favouring the self-directed electrical stimulation intervention group (n=94; SMD 0.50, 95% CI 0.08 to 0.91).

Three of the studies in the constraint-induced movement therapy group were suitable for meta analysis^{13, 21, 25}. Two of these measured changes in arm function using the Wolf Motor Function Test (one using change scores²¹; and the other end score data²⁵) the remaining study used the ARAT¹³. The impact of self-directed constraint-induced movement therapy on arm function indicated a statistically significant effect in favour of the intervention group (n=105; SMD 0.39, 95% CI -0.00 to 0.78).

Four studies^{20, 23, 27, 28} were included in the robotic and orthotic devices group analysis. ARAT change data scores were used from two of the studies^{20, 27} and Fugl-meyer change data scores for the other two. The impact of these programmes did not indicate a statistically significant benefit of the intervention on either arm function (n=171; SMD -0.04, 95% CI -0.35 to 0.27).

Only one study (n=36) reported about use of self-directed mirror therapy, showing no impact on the ARAT (n=36; MD 4.40, 95% CI -6.80 to 15.60).

Only one tele-rehabilitation study met the criteria for meta-analysis²⁷ however, as tele-rehabilitation was not the intervention being tested but rather a means of delivering the

therapy remotely, this study has been included in the robotic devices sub-group of the analysis.

Effects of interventions on independence and self-care activities.

The impact of self-directed interventions on arm use in daily activities was measured by eleven studies. Ten used the Motor Activity Log^{13, 17, 18, 20-22, 24-26, 28} to obtain the participants' perceived use of their stroke arm in thirty daily activities and one provided a post-intervention score of the Nottingham Extended Activities of Daily Living scale¹².

A pooled meta-analysis was carried out on studies reporting the motor activity log "amount of use"^{13, 17, 18, 20-22, 24-26} (Figure 4) and "quality of use"^{13, 17, 18, 20-22, 24-26, 28} (Figure 5) scores. A statistically significant effect favouring the intervention group was demonstrated for both groups of scores: the amount of use (n = 348; MD 0.47, 95% CI 0.27 to 0.67) and the quality of use of the arm (n = 364 participants: MD 0.29, 95% CI 0.12 to 0.46). Analysis within the technology subgroups is described below.

Within the No Technology group, two studies^{17, 26} with 148 participants measured participation in daily activities using the motor activity log. Analysis demonstrated a statistically significant benefit of the intervention on amount of arm use (n=148; MD 0.60, 95% CI 0.07 to 1.13; P value = 0.03) and on the quality of arm movement (n=148; MD 0.52, 95% CI 0.03 to 1.00, P value = 0.04).

No benefit was found for the only included study²² in the interactive gaming group (n=22; MD -0.13, 95% CI -1.15 to 0.8). However, the same study did show a benefit for the participants perceived quality of use of the stroke arm (n=22; MD 1.25, 95% CI 0.27 to 2.23).

Two studies^{18, 24} reported on the benefits of electrical stimulation on independence in daily activities however this was not statistically significant: perceived amount of arm use (n=54; MD 0.20, 95% CI -0.38 to 0.78) and perceived quality of arm use (n=54; MD 0.21, 95% CI -0.37 to 0.79).

Data from three^{13, 21, 25} pooled studies showed a statistically significant benefit of constraint-induced movement therapy on participants ability to carry out daily activities: perceived amount of arm movement (n=105; MD 0.85, 95% CI 0.56 to 1.1, $P<0.00001$); perceived quality of arm movement (n=105; MD 0.75, 95% CI 0.46 to 1.03, $P<0.00001$).

Only one study in the robotic and orthotic devices group measured the amount of use of the stroke arm²⁰ with no benefit found (n=19; MD -0.10, 95% CI -0.49 to 0.29). Two studies^{20, 28} measured the effect of robotic devices on the quality of use of arm but again no benefit was found (n=35; MD -0.25, 95% CI -0.51 to 0.02).

Effect of interventions according to time since stroke onset

All 16 studies were pooled by standardised mean difference to examine the influence of time since stroke onset (Figure 6). No benefit was found at < 3months; 3-6 months or 6 to 12 months post stroke. A statistically significant benefit on arm function was found for patients more than 12 months post stroke (n= 145; SMD 0.61, 95% CI 0.27 to 0.94). The studies included in the post 12 months category included electrical stimulation (n=2; participants = 56)^{14, 18}, robotic devices (n=2; participants = 53)^{23, 28} and mirror therapy (n=1; participants = 36)¹⁹.

Effect of dose of interventions based on the amount of time spent in self-directed therapy

When all studies were pooled, there was no dose-response relationship found between the amount of time spent in self-directed practice and recovery (Figure 7). Further sensitivity analysis was carried out using only data from the electrical stimulation and constraint-induced movement therapy groups (Figure 8) as these had been shown to benefit arm function / impairment. In this analysis only those studies that completed less than 20 hours self-directed therapy practice were found to give a statistically significant benefit relative to controls (n=97; SMD 0.44, 95% CI 0.04 to 0.85), although greater amounts of practice also showed a positive trend.

A risk of bias assessment was carried out for all studies that followed a randomised trial design (see Figure 2). Most studies used an appropriate form of randomisation that ran a low risk of biasing the study. Five were assessed as unclear and one study²⁵ used an alternating

numbers approach which runs a high risk of selection bias. Allocation concealment was adequate in 12 studies^{11-14, 16, 17, 19-22, 26, 27} whilst six were unclear due to the lack of information and one was considered to be of high risk of bias due to the method of randomisation used²⁵.

Blinding of participants in rehabilitation studies is known to be challenging. We found that it was only attempted in the electrical stimulation studies where a sham device was used for the control group^{14, 18, 24}. This appeared to be successful in two studies^{18, 24} whilst reduced compliance for the control group in a third study¹⁴ may have been due to participants becoming unblinded. Successful blinding of outcome assessments was achieved for 13 studies^{13-15, 17-19, 21, 23-25, 27-29}. Two studies^{16, 20} did not attempt to blind outcome assessors and the remaining four studies^{11, 12, 22, 26} reported being unsuccessful.

A further four studies were reported as high risk of bias due to high levels of attrition (>30%)^{14, 22}, unclear reporting of which participants were contributing towards outcome data¹⁶ and under reporting of details for outcomes¹⁵.

Discussion

The evidence base for self-management programmes in stroke care is continuing to grow and supports added benefits of empowerment and self-efficacy that impact positively on the lives of people after stroke⁵¹. Specific aspects however are still largely under-explored⁵² and little is known regarding the delivery of self-directed interventions. Whilst broader self-

management programmes focus on developing the skills required to manage various aspects of an overarching condition⁵², the studies in this review focus on being able to independently initiate and carry out discrete interventions for restoring arm function according to a pre-determined protocol.

The search strategy was broad and attempted to include all methods of self-direction, but may still have been restricted by whether authors had identified their intervention as “self-directed” and the search terms available. To aid this process non-randomised studies were included, but often these studies were small in size, settings were not well described and their poor quality excluded them from our analysis of effects. Overall heterogeneity was substantial in terms of the types of interventions studied, reporting of the amount of self-directed practice and the time post stroke of participants potentially limiting findings.

Of the 38 studies included, some were designed specifically as a self-directed arm intervention^{17, 25, 34-36, 38, 40, 42}, whilst other studies used self-direction as the most convenient mode of delivery. Although the principle underlying their application was similar (i.e. to encourage additional arm motor activity), the technologies described employed different mechanisms of action. A range of outcome measures were used across the studies making it difficult to make direct comparisons. In the absence of studies comparing supervised and unsupervised delivery of the same intervention it is difficult therefore to draw any firm conclusions regarding the efficacy of self-direction as a generic approach.

Thirteen of the 16 randomised studies compared the intervention group against a dose-matched control group^{11, 13, 14, 18-25, 27, 28} which resulted in both groups receiving the same increased dose of therapy. All except one²⁵ of these also followed a self-directed programme. It could perhaps be suggested that both control and intervention groups benefitted from the increased dose, which may explain the small effect sizes between the groups.

There was no clear dose-response found amongst self-directed programmes, although this is confounded by difficulties in being able to accurately report how much practice was performed. Some interventions had built-in mechanisms for recording the amount of practice. Future technology that can accurately capture upper limb practice will greatly assist researchers as well as provide useful feedback to participants during the delivery of self-directed interventions.

Overall there was high compliance across the studies and an ability to follow a self-directed programme suggesting that stroke patients are willing and able to partake in this type of intervention. This may partly reflect the inclusion criteria and selection strategies which identify the most able and enthusiastic volunteers, but the empowering nature of self-direction may also provide a clearer link between what patients are able to do themselves and the possibility of better recovery. High compliance and low attrition seemed to reflect a strong focus on practising tasks that were directly associated with daily activities for example through reach and grasp movements.

Interventions using computer games that were not directly related to functional tasks reported more cases of participants leaving studies, not completing the full amount of self-directed practice and difficulties with recruitment. Feedback from participants suggested that the quality of the gaming experience largely influenced their motivation to continue to engage with the intervention and certainly those that used commercially developed software with more engaging gameplay and graphics showed better compliance for achieving the specified amount of therapy practice.

These may be important findings for developing interventions into effective self-directed programmes and for understanding how theories of self-management can support theories of motor recovery⁵³. Self-efficacy and motivation, have been well documented as key theoretical principles underpinning successful self-management^{54, 55}. Similar virtues of motivating and engaging the player in video games have also been reported on⁵⁶. When designing rehabilitation interventions in general, it is important that the patient remains central to the process throughout⁵⁷. In the absence of a therapist to offer encouragement, it is perhaps even more essential that self-directed interventions have enough relevance and interest to keep the patient motivated and engaged with ongoing practice.

It is generally believed that early intervention will benefit motor recovery and a recent review supported this concept when using interventions employing assistive technology⁵⁸. However, we found that improvements could still occur at a later stage particularly in relation to constraint-induced movement therapy and electrical stimulation. Overall a greater benefit was shown for participants more than 12 months post stroke. Although this may be explained by

active recruitment of participants outside of early rehabilitation for some interventions, it could also be indicative that stroke survivor's readiness to engage in self-directed health programmes may be better later after stroke⁵⁹. It is recommended that future research in this area should consider time post-stroke and perhaps challenge traditional thinking about a narrow early time window with a maximal influence upon recovery³. Usual care at a later time period after stroke is unlikely to involve frequent sessions of supervised therapy, and building up independence in self-management could run in parallel with acquiring independence in rehabilitation activities.

One major limitation was determining what constitutes a self-directed intervention and to what extent the therapy being described in each study was self-directed. The absence of a clear definition created difficulties in developing a robust search strategy and we were required to closely examine the description of each intervention against our own definition and inclusion criteria. Inclusion in this review was therefore largely reliant upon how clearly the authors described the self-directed component of the intervention and there may be other studies employing a self-directed approach that were not included because of the description provided.

In some studies, insufficient information about standard care limited understanding of whether the self-directed approach was simply re-enforcing a more generalised increase in therapy which participants were already undertaking, or if new activities had been introduced. This was particularly challenging for activity programmes prescribed by therapists due to their variable and personalised content. When the intervention appeared to

be facilitating activities which participants were likely to have performed anyway within their daily routine, the study was only included if these were clearly recorded or if they were defined in the study protocol as an intended content of the research. The findings from the search may have been further limited by the reliance of one author for the initial and at times difficult, selection of studies based on our definition of self-directed therapy.

This review highlights that there is a broad range of interventions described as incorporating a self-directed approach to rehabilitation of the arm after stroke. There were many known and unknown differences between the included studies and interventions, which may have more influence upon the results than the self-directed approach. Certain characteristics of self-directed interventions were identified that will aid future research in this area. Amongst intervention subgroups, the most convincing benefit came from constraint-induced movement therapy and electrical stimulation. Constraint-induced movement therapy and therapy programmes without any additional technology were found to have a statistically significant benefit in favour of how much and how well the stroke arm was used in daily activities. These are all relatively low-cost and safe interventions, which show the potential value of offering self-directed therapy. Further research is warranted to identify what key features of self-directed interventions are most effective when incorporated into an arm rehabilitation programme and to focus on consistent terminology to describe the self-directed component of interventions.

Clinical Messages

- A broad range of self-directed interventions for the upper limb after stroke exist including those with and without technology.

- Constraint-induced movement therapy, electrical stimulation and no technology programmes appear the most effective self-directed approaches to benefit arm function or independence in daily activities.

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Competing interests

None declared

Contributors

RDS: Initiating and designing the review; analysis and interpretation of data; writing the paper and making amendments to draft articles following review; final approval of version to be published.

SM: analysis and interpreting the data; reviewing draft article critically for important intellectual content and final approval of the version to be published.

CP: designing the review; analysis and interpretation of data; reviewing draft article critically for important intellectual content and final approval of the version to be published.

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TABLE 1 – Description of self-directed interventions

No technology								
<i>Details of intervention /device</i>	<i>First Author, year, country</i>	<i>Study protocol</i>	<i>Study design Recruited (n=) Mean Time post stroke</i>	<i>Self-directed practice (hours)</i>	<i>Supervised practice (hours)</i>	<i>% self-directed practice</i>	<i>Adherence to amount of independent practice</i>	<i>Authors' conclusion</i>
Repetitive functional task practice two tasks chosen from a menu of daily activities. 20 repetitions practised twice daily.	Brkic, 2016 UK ¹²	4 week programme of twice dailyself-supervised practice. Twice-weekly therapy review of goals and tasks. Daily practice recorded on log sheets. Control group received usual care.	Pilot RCT (n = 24) <3 months	28	6	82%	Patients adhered well to twice daily practice over 4 weeks	Intervention was acceptable and led to achievement of goals but fatigue levels require monitoring
Graded repetitive arm supplementary programme (GRASP). Participants complete 1 hour a day of self-administered exercise programme from a manual.	Harris, 2009 USA ¹⁷	4 week program; 60minutes per day, 6 days a week. Daily practice recorded on log sheets. Weekly review from a therapist. Control group provided with education book on stroke recovery and general health.	RCT (n = 103) <3 months	24	2	92%	1 hour a day for 4 weeks was feasible	Intervention is feasible and offers a low-cost method of delivery for maximising time spent on arm recovery
Self-directed exercise programme with task board and paper and glass cups. Graded according to ability to carry out repetitive reach and grasp tasks.	Lee, 2013 Republic of Korea ³⁵	10 week programme of 60 minutes unsupervised practise twice a week; Weekly 1 hr session with physiotherapist..	Before-after (n = 7) >12 months	20	10	67%	Twice weekly practice of programme was feasible	Self-directed exercise using a task board can improve function and reduce pain in the stroke arm.
3 hour self-directed practice consisting of 15 minutes self-mobilization exercises; 90 minutes unimanual task practise (bringing cup to mouth, stacking cups; reaching for water bottles; moving cutlery and coins; turning cards) and 40 minutes bimanual task practice (buttons; folding napkin and opening a bottle)	Natta, 2015 Benin ³⁸	2 week programme; 3 hours practice per day for 5 days/week over 2 weeks. Telephone review every two days to monitor progress.	Before-after (n = 12) >12 months	30	2.25	93%	3 hours a day practice was feasible	Self-directed therapy is feasible and inexpensive and could increase the number of rehabilitation sessions to improve recovery
Progressive training programme of whole reach-to-grasp tasks and part practice activities aiming to achieve 100-300 repetitions per session.	Turton, 2016 UK ²⁶	6 week programme. One hour self-directed practice per day. 14 x one hour therapy sessions over the six weeks. Daily practice recorded on log sheets. Control group received usual care.	RCT feasibility (n = 48) 3-6 months	42	14	75%	Participants achieved median 30 minutes self-practice per day	Home-based intensive task-specific rehabilitation is safe and feasible.

TABLE 1 – Description of self-directed interventions

Interactive gaming								
<i>Details of intervention / device</i>	<i>First Author, year, country</i>	<i>Study protocol</i>	<i>Study design Recruited (n=) Mean Time post stroke</i>	<i>Self-directed practice (hours)</i>	<i>Supervised practice (hours)</i>	<i>% self-directed practice</i>	<i>Adherence to amount of independent practice</i>	<i>Authors' conclusion</i>
Nintendo Wii sports™ Commercially available video game offering non-immersive virtual reality therapy.	Adie, 2016 UK ¹¹	6 week programme. Self-directed exercise using the Nintendo Wii sport™ games for 45 minutes per day in seated position. Weekly telephone review. Control group practised tailored arm exercises 45 minutes per day for 6 weeks	RCT (n = 240) <3 months	31.5	1.5	95%	Participants achieved a mean of 39 minutes practice per day	Wii™ based exercise was safe and well tolerated but improvements were not superior to less expensive alternatives.
	Mouawad, 2011 Australia ³⁷	2 week programme. Self-directed exercise using the Nintendo Wii sport™ for 30 mins increasing to 3 hours per day; additional 1 hr per day of supervised training.	Before-after (n = 7) >12 months	22	10	69%	Participants achieved a mean of 2.4 hours practice per day	Intervention led to improvements in motor function which also benefitted use of stroke arm in activities of daily living.
Neurogame Therapy system Surface EMG-controlled video games to target wrist activation. Surface electromyography signals from wrist flexors and extensors transmitted to computer and converted into movements to control the game.	Donosos, 2014 USA ³³	4 week programme. 45 mins self-directed practice x 5 days a week for four weeks (or total of 15 hours). Intermittent support as required during the 4 weeks (estimated at 2 visits over the 4 weeks).	Repeated measures (n = 12) >12 months	15	1	94%	Five sessions weekly not feasible. Fewer sessions of longer duration may be more	Intervention benefitted muscle activation but limited changes in kinematic and activity level outcomes indicate need for additional functional component.
Virtual glove Hand-mounted unit with infra-red light emitting diodes mounted to fingertips. Nintendo Wiimotes on monitor tracks diodes to translate hand movements into 3D space. 3 games encourage reach and grasp, grasp and release and pronation / supination.	Standen, 2017 UK ²²	8 week programme. Self-directed practice of 20 minutes maximum, 3 times a day. Weekly or fortnightly review visits offered. Control group received no input other than visits to collect outcome measures.	Pilot RCT (n = 29) 6-12 months	56	4	93%	Low recruitment and retention rates. Higher than expected levels of support required (median 6hrs 10 minutes of support per person).	Additional strategies required to boost recruitment and adequate resources to support participants with the technology.
Armeo®Senso Sensor-based virtual reality training session with touchscreen computer and wearable movement sensors to offer high dose repetitions via computer therapy games.	Wittman, 2015 Switzerland ⁴⁷	6 week programme. As much practice as they chose playing virtual reality reaching game. No additional support was provided	Non-randomised feasibility study (n = 5) not reported	17	0	100%	Average amount of time spent on playing was 16.8 hours over 6 weeks.	Intervention is viable option for home therapy
	Wittman, 2016 Switzerland ⁴⁶	6 week programme. As much practice as they chose playing VR reaching game. No additional support was provided	Before-after (n = 11) >12 months	14	0	100%	Average daily time spent practising was 30 minutes for 4 days per week (mean 13.7 hours over 6 weeks).	IMU-based home therapy is safe and offers high dose of therapy

TABLE 1 – Description of self-directed interventions

<i>Electrical stimulation</i>								
<i>Details of intervention / device</i>	<i>First Author, year, country</i>	<i>Study protocol</i>	<i>Study design Recruited (n=) Mean Time post stroke</i>	<i>Self-directed practice (hours)</i>	<i>Supervised practice (hours)</i>	<i>% self-directed practice</i>	<i>Adherence to amount of independent practice</i>	<i>Authors' conclusion</i>
Handmaster™ system Neuroprostheses maintains wrist in 10-20 degree extension and delivers electrical stimulation through 5 surface electrodes to stimulate flexion / extension of fingers to grasp and release objects.	Alon, 2002 USA; Israel ³⁰	3 week functional programme. 10 minutes increasing to 45mins self-directed practice twice daily.	Before-after study (n = 29) >12 months	37	2	95%	Good compliance with programme	Handmaster is safe and effective for improving hand function
	Alon, 2003 Sweden; The Netherlands; Israel ³¹	5 week functional programme. 20mins daily increasing in the first 2 weeks up to 2hrs 45mins daily to be practiced for the remaining 3 weeks	Before-after (n = 77) >12 months	75	2	97%	High compliance supported use of FES of up to 2hrs 45 mins practice per day	5 week programme improved selected hand functions
Electrical stimulation using closed-loop control of micro stimulator implants to activate elbow extension, wrist extension, finger / thumb extension and thumb abduction when reaching and grasping.	Burridge, 2011 UK ³²	12 week programme; 1-2 hours per day at home for 12 weeks plus x 3 review sessions by researcher (one every 4 weeks).	Before-after (n = 6) >12 months	72	1.5	98%	Participants achieved a mean of 59.5 days of unsupervised practice	Closed-loop stimulation improved function but subjects reported inconvenience using. A fully implanted wireless version would overcome this.
Reliefband® device to deliver repetitive peripheral nerve stimulation prior to motor training tasks. Bi-phasic square-wave electrical nerve stimulation delivered via surface electrodes built into style device at frequency of 31 Hz. 5 different levels of stimulation.	Dos Santos-Fontes, 2013 Brazil ¹⁴	4 week programme for 2 hours before motor training tasks. 2 blocks of training per day over 4 weeks. Therapy review at 7 days to ensure correct procedure and weekly review thereafter. Control group wore wristband on dorsal surface of wrist thick polyester barrier to prevent electrical stimulation to nerve	Pilot RCT (n = 20) >12 months	42	1.25	97%	High compliance with intervention reported	Intervention is safe and feasible leading to long-lasting enhancement of arm function.
Neuromove 900 – uses 3 surface electrodes to detect electromyography in affected muscles and deliver electrical stimulation to them if muscle activity exceeds a preset threshold.	Gabr, 2005 USA ¹⁵	8 week programme of twice daily use of 35 minutes whilst practising extension exercises. Control group 8 weeks home exercise programme for 35minutes per day. Bot groups cross over following initial 8 weeks programme	Cross over RCT (n = 12) >12 months	65	0	100%	High compliance with intervention reported by completed patient diaries	Intervention is feasible and increased active wrist extension. No functional benefits were found.
Power-assisted closed-loop electromyographically triggered electrical stimulation system worn under clothes to induce greater muscle contraction than EMG signal detected. Targets supination/pronation, flexion/extension of digits, wrist and elbow; abduction/adduction of shoulder	Hara, 2008 Japan ¹⁶	5 month programme; 30 min self-directed programme 5 days a week gradually increasing to 1hr per day within the first 10 days. Thereafter 1hr per day 5 days a week for 5months.	RCT (n = 22) >12 months	106	15	88%	10 out of 12 participants were able to comply with the full five month programme	Intervention benefitted wrist and finger extension and shoulder flexion.

TABLE 1 – Description of self-directed interventions

Electrical stimulation (continued)								
<i>Details of intervention / device</i>	<i>First Author, year, country</i>	<i>Study protocol</i>	<i>Study design Recruited (n=) Mean Time post stroke</i>	<i>Self- directed practice (hours)</i>	<i>Supervised practice (hours)</i>	<i>% self- directed practice</i>	<i>Adherence to amount of independent practice</i>	<i>Authors' conclusion</i>
Automove Model AM 706 stimulator Electromyography triggered somatosensory stimulation to peripheral nerves to facilitate hand opening	Kimberley, 2003 USA ¹⁸	3 week programme of 6 hours a day over 10 days. Half the time participant triggered stimulated response through active effort, rest of time machine automatically stimulated muscle contraction. Control received same programme using sham device before cross-over	RCT crossover (n = 16) >12 months	60	0.75	99%	All participants achieved 60 hours typically through 3-6 hours every day or every other day.	Intervention self-administered in an intensive manner is feasible. Improvements lead to improvements in hand function.
Mentamove neuromuscular electrical stimulation device detects electrical signals in muscle group and activates muscle if EMG activity meets or exceeds preset threshold.	Page, 2015 USA ⁴¹	8 week programme of mental practice-to trigger muscle activation. Patients imagined carrying out 2 upper limb tasks without actually moving. Device detected if electrical signals sent to targeted muscle group met threshold and if so activated muscle; 1hr per day	pre-post case series design (n = 6) >12 months	56	2	97%	High compliance with intervention	Intervention appears to be feasible and benefitted arm impairment, dexterity and participation in activities.
Rehabilitcare EMS +2 Muscle stimulator with Stimcare + electrodes.	Sullivan, 2007 USA ⁴⁴	8 week programme of neuromuscular and sensory amplitude electrical stimulation during task-specific exercises for 15 minutes once or twice daily. Sensory stimulation 15 minutes twice daily for participants with sensory deficits.	Before-after (n = 10) >12 months	56	none reported	100%	Poor completion of log books but all participants completed the programme	Intervention is feasible and led to sensory and motor improvements.
Glove electrode with electrical stimulation delivered by EMPI 300 PV neuromuscular stimulator.	Sullivan, 2012 USA ²⁴	4 week programme sensory electrical stimulation delivered during 10 task-specific arm exercises. Twice daily for 30 minutes 5 days a week. Control group followed same programme using a sham device	RCT (n = 43) 6-12 months	20	none reported	100%	High compliance with the intervention	Intervention did not benefit task practice. Future studies should explore of more intensive practice leads and if stimulation is better before or during the task practice.
Radiofrequency microstimulator implanted in arm and forearm to activate elbow, wrist and finger extension and thumb abduction while performing functional tasks	Turk, 2008 UK ⁴⁵	12 week programme; 12 weeks self-supervised practice of 1 hour per day 5 days a week. Weekly to fortnightly lab-based sessions with research therapist to adjust device.	Before-after (n = 7) >12 months	60	15	80%	High compliance with the intervention	Intervention was feasible and led to improvements. Personalising the intervention around the subjects led to higher motivation/compliance.

TABLE 1 – Description of self-directed interventions

Constraint-induced movement therapy								
<i>Details of intervention / device</i>	<i>First Author, year, country</i>	<i>Study protocol</i>	<i>Study design Recruited (n=) Mean Time post stroke</i>	<i>Self-directed practice (hours)</i>	<i>Supervised practice (hours)</i>	<i>% self-directed practice</i>	<i>Adherence to amount of independent practice</i>	<i>Authors' conclusion</i>
Task-related arm training delivered by therapist plus unilateral self-directed programme following shaping principles and based around activities of daily living. Constraint mitt worn for 4 hours. Daily log of time spent exercising.	Brunner, 2012 Norway ¹³	4 week programme; 4 hours a week supervised therapy as in/outpatient plus 2-3 hours a day self-directed functional programme. constraint mitt worn for 4 hours a day. Control group followed a similar programme but with bimanual tasks.	RCT (n = 30) <3 months	56	16	78%	Participants were able to achieve the required amount of self-directed practice and wore the mitt for a mean of 3.5 hours per day.	Intervention was as effective as bimanual training and therefore wearing a mitt may be unnecessary. Programmes should include bimanual tasks.
Web-supported programme (LifeCIT) incorporating instructions guiding participants through the programme, setting of daily targets for constraint mitt wear time and time spent on exercises, computer-based therapy games and activities of daily living.	Burridge, 2017 UK ²⁹	3 week programme. Intervention group accessed the programme 6 hours a day, 5 days a week for 21 days. Control group received usual care	Pilot RCT (n = 19) <3 months	90	0	100%	High compliance with intervention. Mitt worn for mean 4.8 hours per day for 13.6 out of 15 days. Activities performed for mean 3.2 hours per day.	A web-supported programme of constraint-induced movement therapy can increase intensity and adherence.
Modified constraint-induced movement therapy programme delivered via tele-rehabilitation.	Page, 2007 USA ⁴⁰	10 week programme; 3 half hour therapy sessions per week delivered via tele-rehabilitation; mitt worn for 5 hours daily and participants recorded ADLs performed during this time	Before-after case series (n = 4) >12mths	350	16	95%	Good adherence to the programme. Participants and therapists reported high satisfaction.	Delivery of constraint-induced movement therapy via the internet is feasible and inexpensive.
Constraint-induced movement therapy programme delivered via video-conferencing equipment	Pickett, 2008 USA ⁴²	2 week programme; 6 hrs per day self-directed practice 5 days a week with 1.5hrs per day of tele-rehabilitation support from therapist (split across morning and afternoon)	Before-after case series (n = 2) >12 months	60	15	80%	Patients reported moderately high time demands for the intervention and difficulty reconciling times for therapy reviews.	Partial confirmation that intervention is effective. Need to streamline delivery with more portable equipment.
Modified constraint-induced movement therapy programme consisting of daily outpatient session and self-directed practise of 30 household activities.	Smania, 2012 Italy ²¹	2 week programme. 1 hour individual treatment sessions as outpatient in morning and 1 hour self-directed household activities in afternoon 5 days a week for 2 weeks. Constraint splint worn for 12 hours per day. Control group received 1 hour therapy and 1 hour self-directed household tasks.	RCT (n = 66) 6-12 months	10	10	50%	Participants were able to adhere to the programme	Two hours of constraint induced movement therapy a day may be effective than conventional therapy.
Daily restraining of hand whilst carrying out intensive training activities based on participants activities of daily living. Training recorded in log sheets.	Tariah, 2010 Jordan ²⁵	2 month programme, 2 hours a day, 7 days a week. Control group received dose matched neuro-developmental therapy.	RCT (n = 20) 6-12 months	120	none reported	100%	All participants adhered to the intervention.	The intervention was feasible and led to improvements in arm function.

TABLE 1 – Description of self-directed interventions

Robotic and dynamic orthotic devices								
<i>Details of Intervention / device</i>	<i>First Author, year, country</i>	<i>Study protocol</i>	<i>Study design Recruited (n=) Mean Time post stroke</i>	<i>Self-directed practice (hours)</i>	<i>Supervised practice (hours)</i>	<i>% self-directed practice</i>	<i>Adherence to amount of independent practice</i>	<i>Authors' conclusion</i>
HandSOME (Hand spring operated movement enhancer) to extend fingers in grasp and release tasks and logs movement data.	Chen, 2017 USA ⁵⁰	4 week programme; 90 minutes per day x 5 days per week. Graded unimanual and bimanual tasks eg fill water bottle, pick and place objects. Weekly therapy review.	Before-after (n=10) >12 months	30	2	94%	Practice ranged from 3 to 33 hours. 3 participants unable to don/doff device.	Gains after intervention were not sustained. Improvements to donning and doffing device needed.
Saebo Mobile Arm support (SaeboMAS) Gravity compensation of proximal arm with Supervised Care and Rehabilitation Involving Personal Telerobotics (SCRIPT) dynamic wrist / hand orthosis for passive extension of arm, wrist and hand task. Computer games and remote monitor practice.	Nijenhuis, 2015 Netherlands; Italy; UK ³⁹	6 week programme; 30 mins per day x 6 days per week. Weekly home visit review of 15 minutes and daily remote monitoring of progress and training adjustments.	Feasibility study (n = 24) >12 months	18	1.5	92%	Mean of 1.75 hours per week of self-directed practice.	Intervention is feasible and improved function and quality of life but not dexterity.
	Nijenhuis, 2017 Netherlands ²⁰	6 week programme; 30 mins per day x 6 days per week. Weekly home visit review. Control group performed conventional home exercise programme.	Pilot RCT (n = 20) 6-12 months	18	1.5	92%	Mean of 2 hours per week of self-directed practice.	No benefit found and control group reported higher training duration.
Home-based computer assisted arm rehabilitation robotic device (hCAAR) Joystick handle linked to robotic arm to complete tasks on computer screen	Sivan, 2014 UK ⁴³	8 week programme. 30 minutes a day 5 days a week; fortnightly therapist telephone call.	Feasibility study (n = 19) > 12 months	20	1	95%	Lower dose of practice than requested. Median 7.2 hours practice over the 8 weeks.	Intervention improved arm movement and function. Improvements could be made to the games.
Active-passive bilateral therapy (APBT) device mechanically couples hands to allow stroke arm to mirror rhythmic flexion-extension of non-paretic wrist. Used to prime the motor system prior to tasks.	Stinear, 2008 New Zealand ²³	1 month programme. 10-15 minutes APBT followed by 10 minutes task training performing 2 repetitive motor tasks with wooden blocks x3 daily. Control group performed the same tasks without the priming with APBT.	RCT (n = 32) >12 months	30	none reported	100%	High compliance with intervention	Both groups benefitted from self-directed motor practice. Intervention group had additional neurophysiological changes to the motor cortex.
Hand mentor pro™ Robotic active-assist device worn on forearm and paired with video games to improve active range of movement in wrist and fingers. Remote monitoring of use through tele-rehabilitation.	Wolf, 2015 USA ²⁷	8 week programme. 2 hours practise with device plus one hour of functional activities 5 days a week. Weekly contact via telephone / email. Control group performed 2 hours traditional exercises and 1 hour functional activities.	RCT (n = 99) 3-6 months	120	2	98%	High compliance with intervention	Both groups benefitted from self-directed approach. Added benefit of Robot group was additional information for the therapist.
Robotic upper extremity repetitive therapy (RUPERT IV) Wearable robotic exoskeleton system assists shoulder/ arm / hand movements to reach for 3-D virtual targets. Monitored remotely.	Zhang, 2011 Switzerland ⁴⁸	4 week programme. 45 minute sessions 1-2 times each weekday for 4 weeks. Weekly review visit from therapist.	Before-after (n = 2) >6 months	15	2	88%	Participants were able to complete the programme	Inconclusive results due to small sample size and wide variation between participants.
Resonating arm exerciser Mechanical device encourages shoulder and elbow flexion/extension to roll wheelchair back and forth.	Zondervan, 2014 USA ²⁸	3 week programme of resonating arm exercises. 3 hours per week for 3 weeks. Weekly phone contact from therapist. Control group were given booklet of conventional exercises.	RCT cross-over (n = 17) >12 months	9	0.75	92%	High compliance with intervention. Participants were able to complete about 10 hours of self-directed practice.	Home-based training was feasible and reduced impairment.

TABLE 1 – Description of self-directed interventions

Mirror therapy								
<i>Details of intervention / device</i>	<i>First Author, year, country</i>	<i>Study protocol</i>	<i>Study design Recruited (n=) Mean Time post stroke</i>	<i>No.of hours self-directed practice</i>	<i>No. of hours supervised practice (hours)</i>	<i>% self-directed practice</i>	<i>Adherence to amount of independent practice</i>	<i>Authors' conclusion</i>
Mirror therapy Instruction booklet with photographs and video of exercises.	Michielson, 2011 Netherlands ¹⁹	6 week program; 1 hour per day x 5 days a week for 6 weeks. Weekly 1 hour therapy review with therapist and telephone calls. Control group performed same programme but with direct view of both hands.	RCT (n = 40) >12 months	30	6	83%	High compliance with average of 30 hours of self-directed practice.	Improvements to motor function found. Further research into optimum practice intensity and duration required.
Tele-rehabilitation								
Task specific training programme presented on laptop screen. Equipment for modular tasks to support fine motor tasks, stereognosis, tactile discrimination and object manipulation. Guidance and support provided via video conferencing.	Langan, 2013 USA ³⁴	6 week programme. 1 hour practice a day for 5 days a week. Daily monitoring via internet video conferencing reduced to once a week by final week.	Before-after (n = 7) >12 months	30	3.5	90%	Good adherence to the programme - over 90% compliance.	Tele-rehabilitation is viable and offers feedback based on one-to-one supervision or data acquired during training
SMART rehabilitation system – x2 motion sensors track arm movements and communicate information to computer interface via Bluetooth. Feedback on exercise performance provided to the wearer.	Mawson, 2011 UK ³⁶	2 week programme of computer aided repetitive reaching exercises carried out daily.	Before-after study (n = 4) >6 months	7	none reported	100%	Good adherence to the programme	The SMART system may be a more cost-effective and effective method of delivering therapy.
Wearable devices								
Wrist-worn accelerometer with prompt alert function is programmed to provide up to hourly feedback to the wearer on their stroke arm activity levels. Therapy reviews offer opportunity to view activity data on computer interface and set activity targets for next few days.	Da Silva, 2018 UK ⁴⁹	4 week repetitive task programme to encourage stroke arm use within activities of daily living whilst wearing the watch. Amount of practice based on individual baseline activity levels. Twice weekly therapy reviews to view data and task practice and to reset activity targets	Before-after study (n = 11) <1 month	Not reported in hours	8	n/a	Adherence was good	Feedback delivered by the accelerometer increased arm activity. Participants favoured hourly prompts with a low prompt threshold.

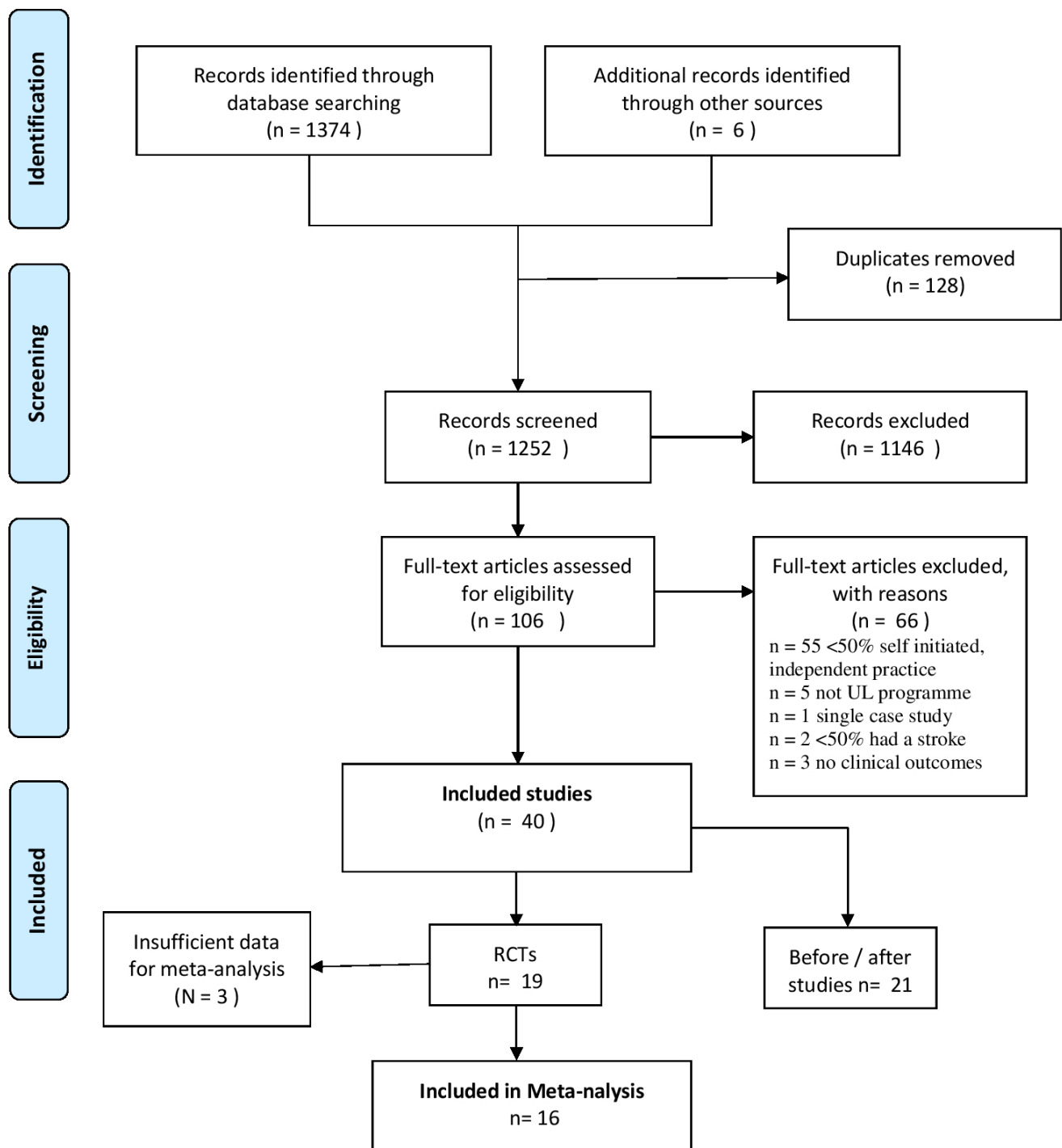


Figure 1. PRISMA diagram of the process used to identify studies¹⁰

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)
Adie 2016	+	+	-	?	+	+
Brkic 2016	+	+	-	?	+	+
Brunner 2012	+	+	-	+	+	+
Burridge 2017	?	?	-	+	?	?
Dos Santos-Fontes 2013	+	+	+	+	-	+
Gabr 2005	+	?	-	+	?	-
Hara 2008	+	+	-	-	?	-
Harris 2009	+	+	-	+	+	+
Kimberley 2004	?	?	+	+	+	+
Michielsen 2011	+	+	-	+	+	+
Nijenhuis 2017	?	+	-	-	+	+
Smania 2012	+	+	-	+	+	+
Standen 2017	+	+	-	?	-	?
Stinear 2008	?	?	-	+	?	?
Sullivan 2012	+	?	?	+	+	?
Tariah 2010	-	-	-	+	?	?
Turton 2016	+	+	-	?	+	+
Wolf 2015	+	+	-	+	+	?
Zondervan 2015	?	?	-	+	+	+

Figure 2: Risk of bias summary: review authors' judgements for each included RCT study.

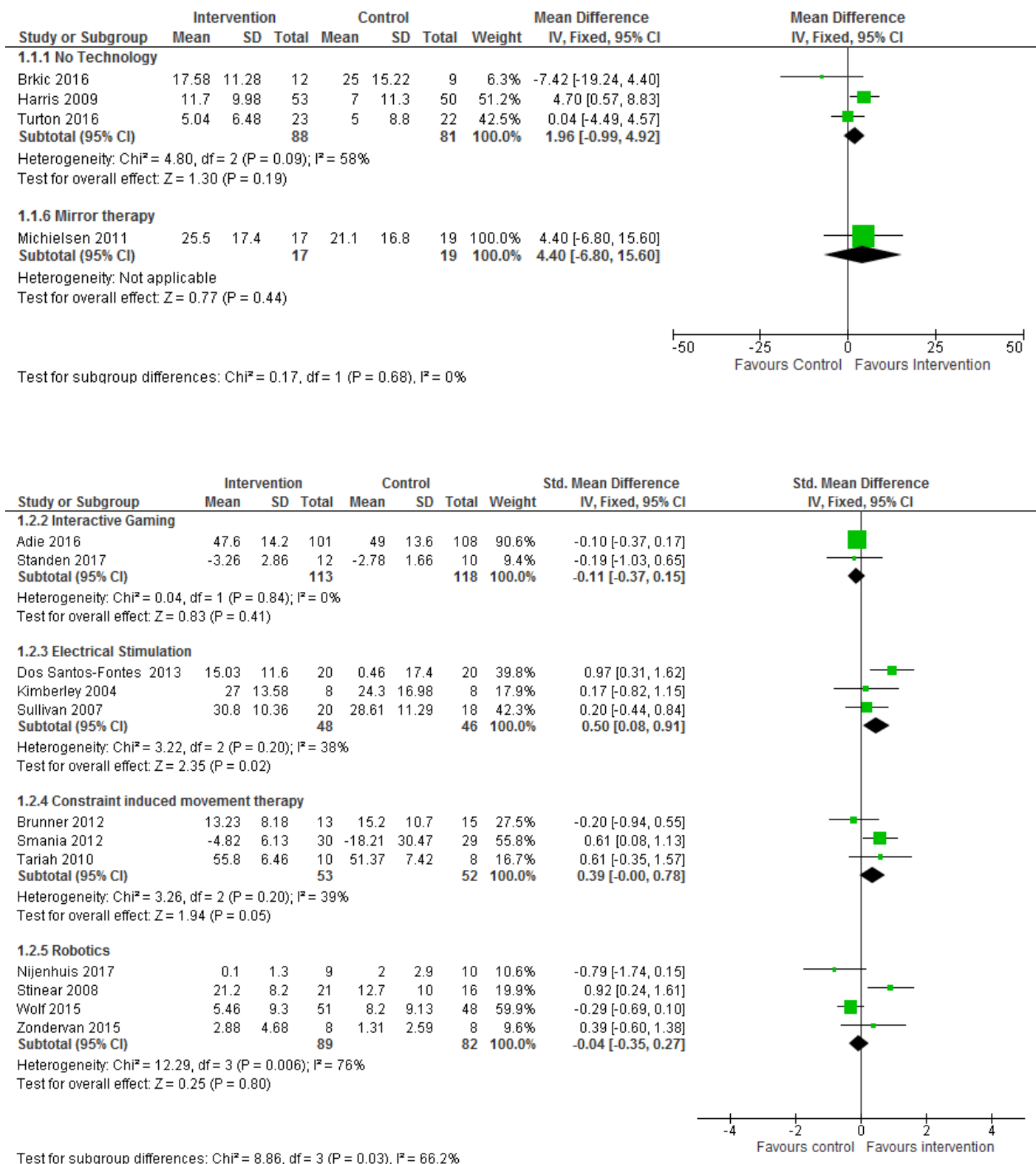


Figure 3: Treatment effect of self-directed intervention on arm function

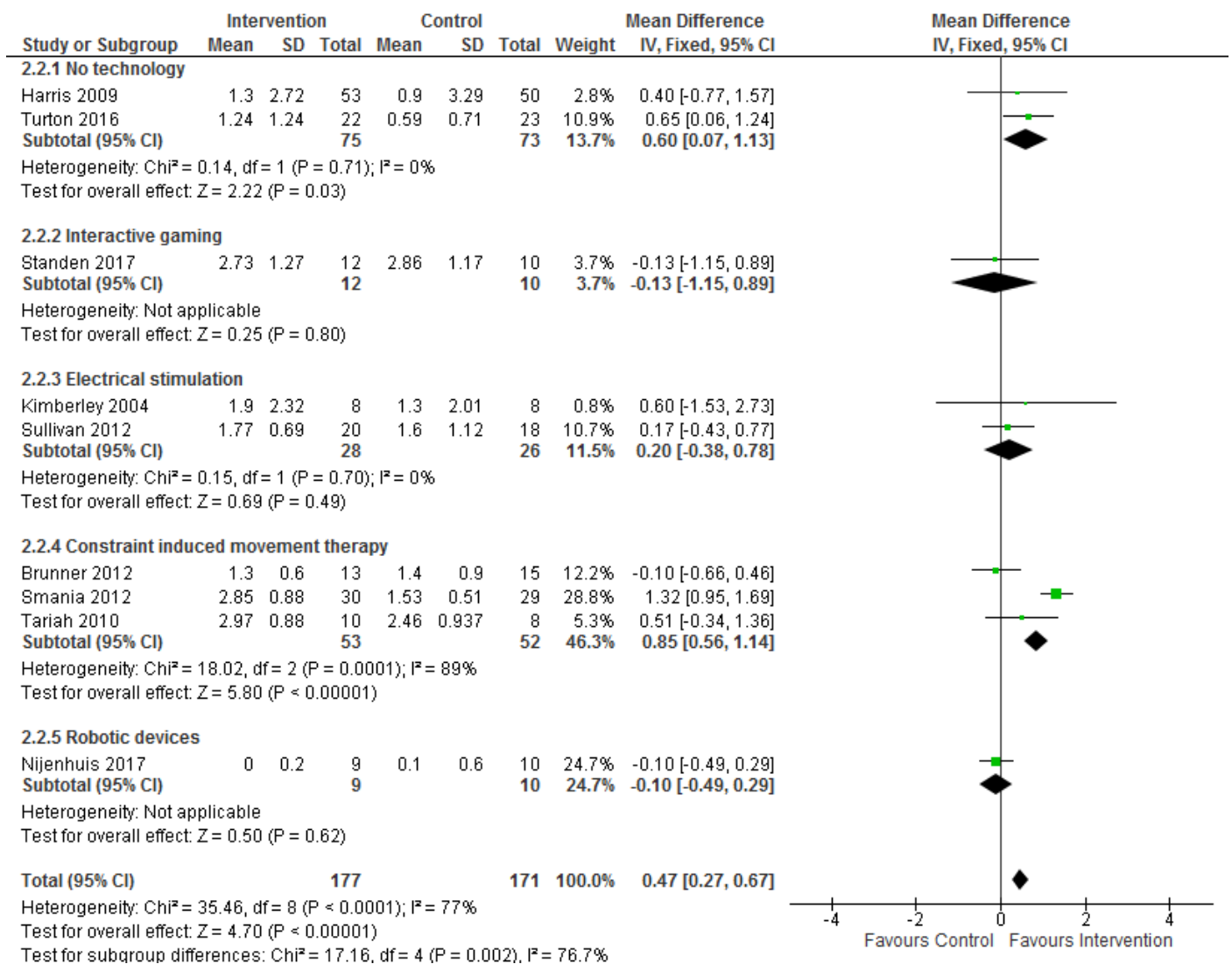


Figure 4: Treatment effect of self-directed interventions on perceived amount of use of the stroke arm

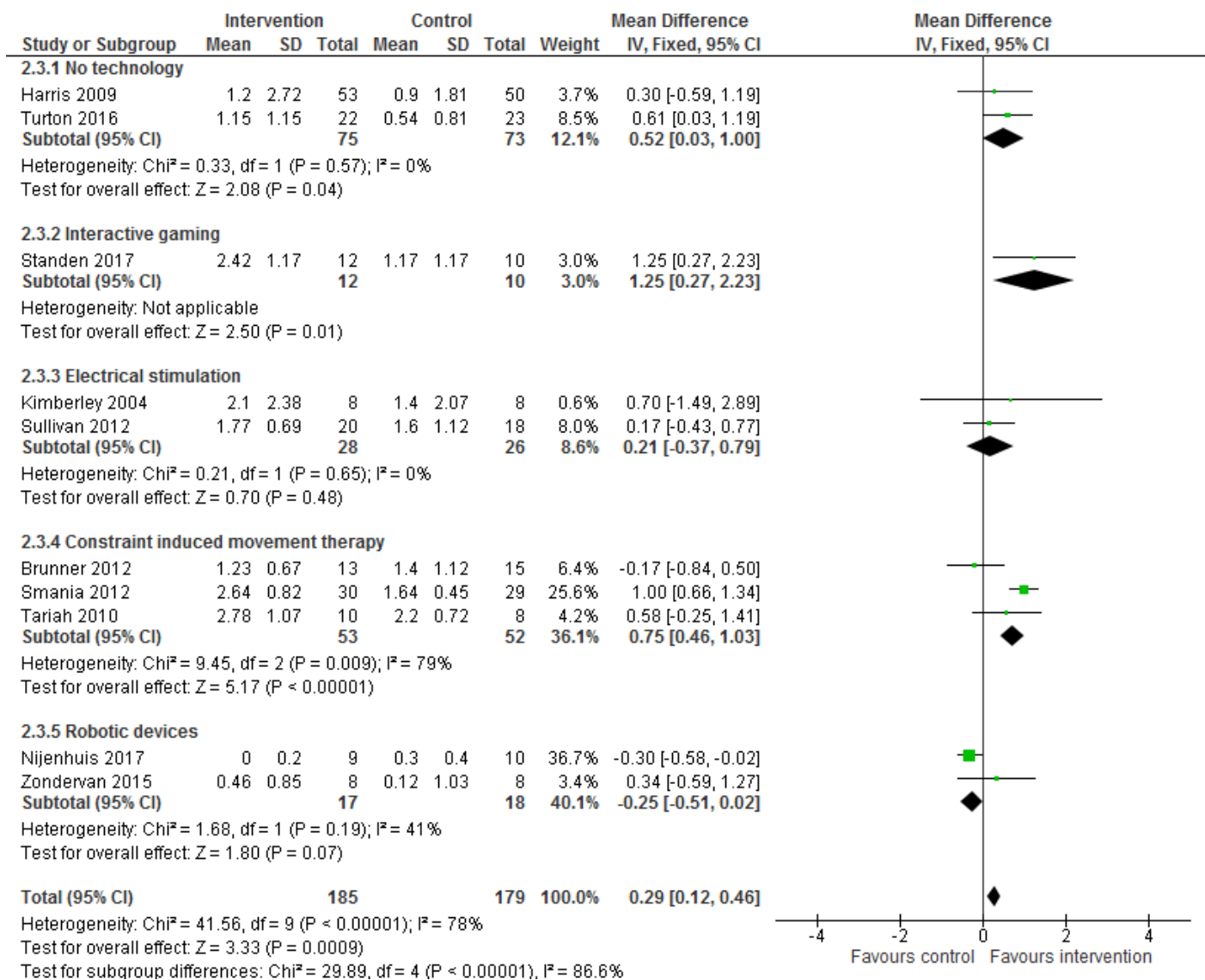


Figure 5: Treatment effect of self-directed interventions on perceived quality of use of the stroke arm

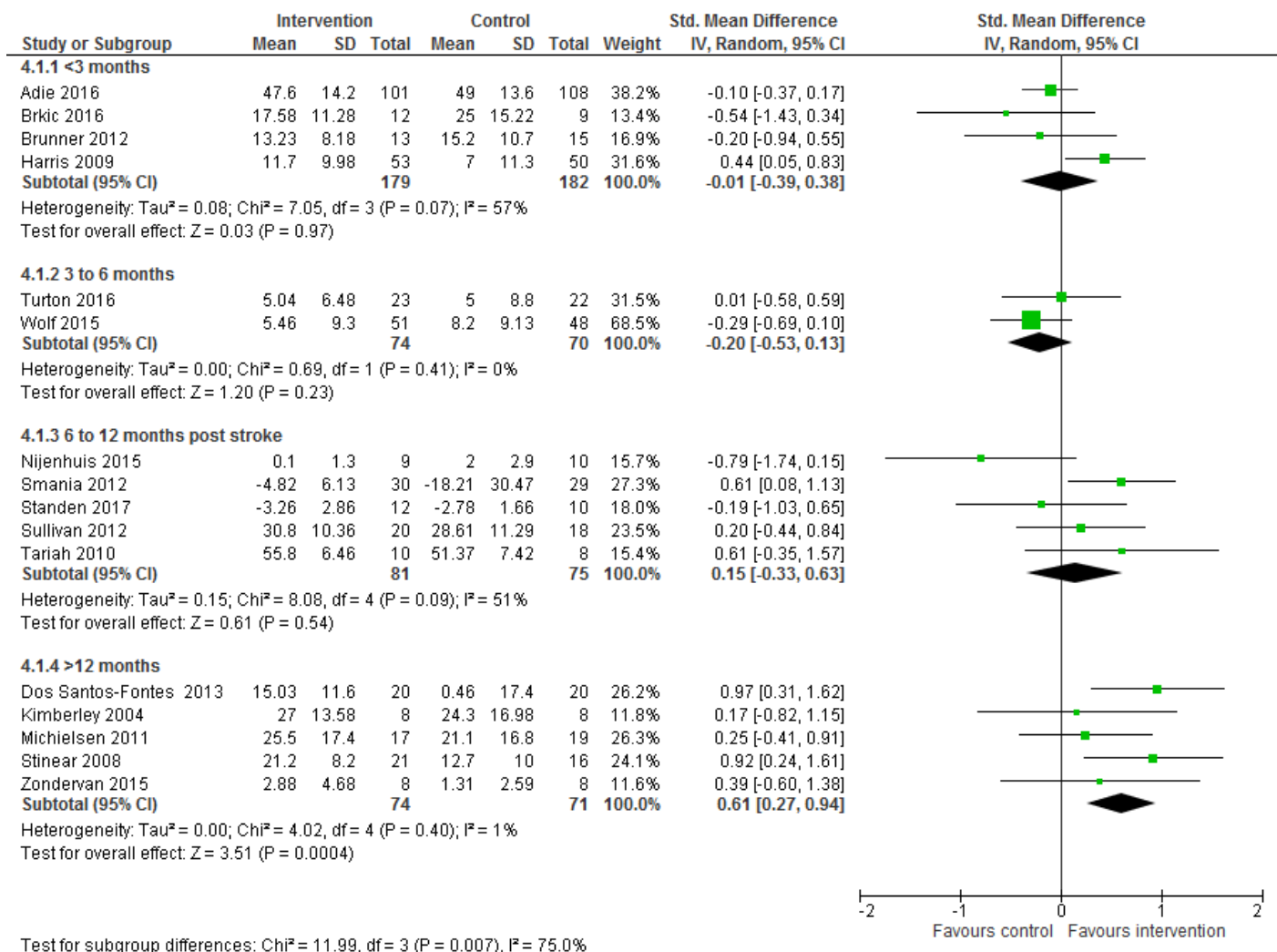


Figure 6: Effect of time since stroke on arm recovery

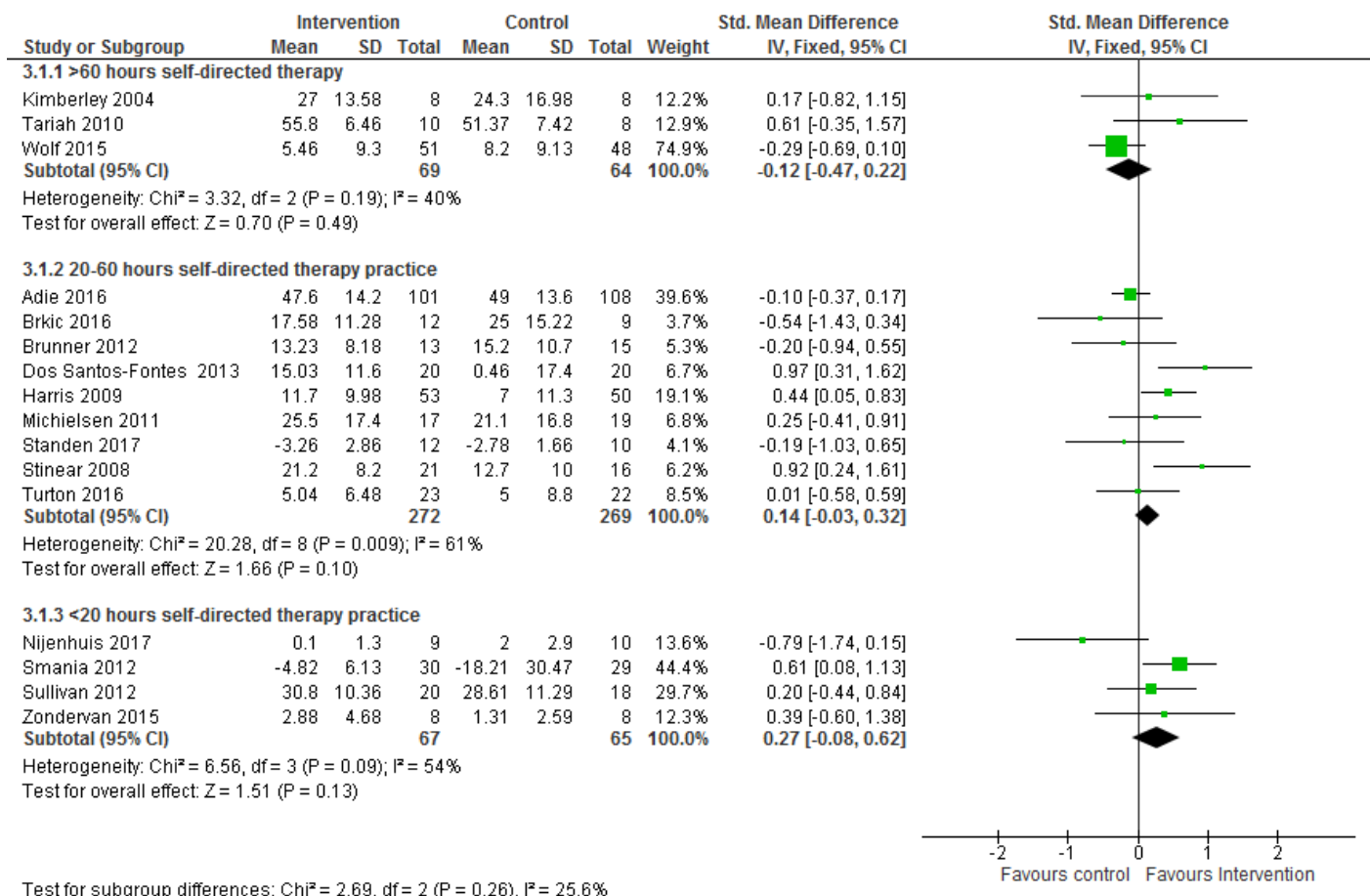


Figure 7: Effect of dose of self-directed therapy on arm function

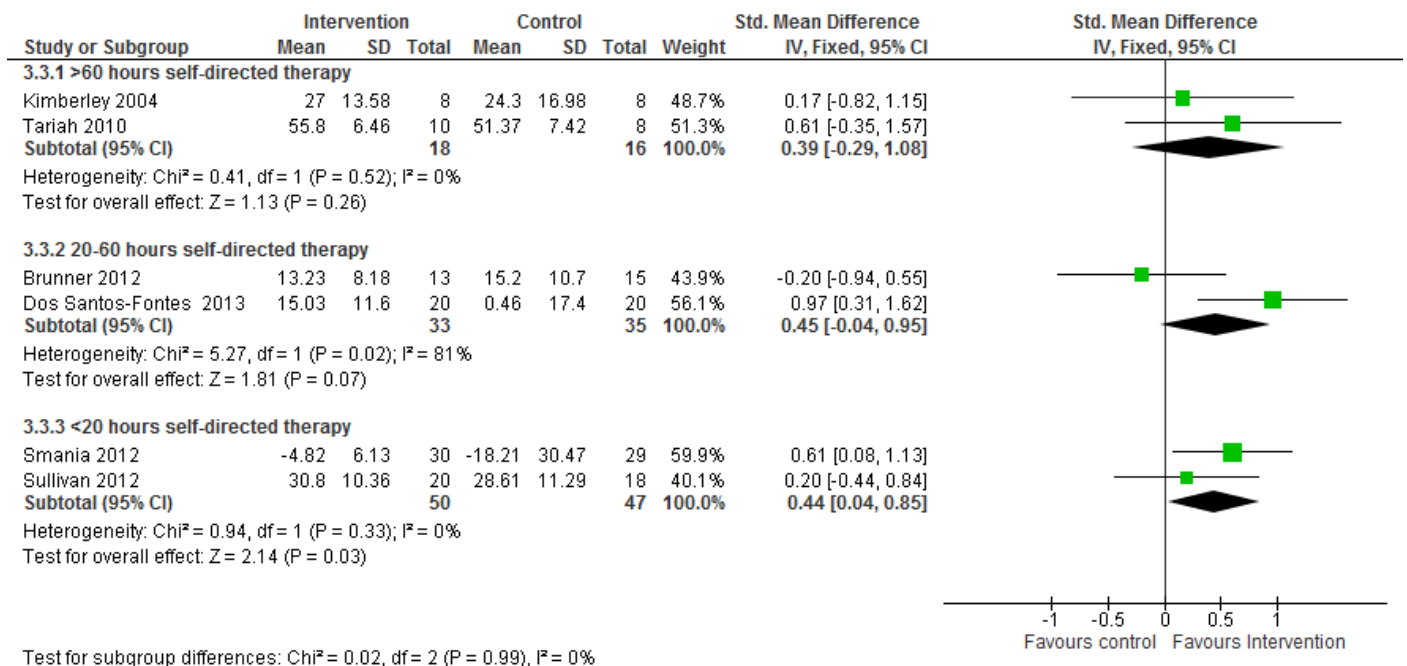


Figure 8: Effect of dose of self-directed therapy on arm function (CIMT and ES combined)

Appendix 1

Medline Search Strategy

1. Stroke/rh, th [Rehabilitation, Therapy]
2. exp upper extremity/ or exp arm/ or exp axilla/ or exp elbow/ or exp forearm/ or exp hand/ or exp shoulder/
3. 1 and 2
4. self-administer*.mp.
5. self-care.mp.
6. self-direct*.mp.
7. self-manag*.mp.
8. self-supervised.mp.
9. home-based.mp.
10. thera*.mp.
11. practise.mp.
12. extra.mp.
13. supplement*.mp.
14. enhanced.mp.
15. physical therapy.mp.
16. physiotherapy.mp.
17. exercise therapy.mp.
18. occupational therapy.mp.
19. 4 or 5 or 6 or 7 or 8 or 9 or 11 or 12 or 13 or 14
20. 10 or 15 or 16 or 17 or 18
21. 3 and 19 and 20